HUMAN VENTILATION AND BREATHING PATTERNS: NORMAL VALUES AND RANGES

David Caretti
Research Physiologist
Edgewood Chemical Biological Center

15 October 2003

Background

- Objectives
  - Define ventilatory parameters based on real-world work rates
  - Examine both non-respirator and respirator conditions
  - Establish flow rates for assessing filter/respirator performance

- Approach
  - Literature review
  - Compile/analyze data from government/non-government sources
  - Human use testing (lab and/or worksite)

Progress

- Literature Search
  - Collected > 100 articles
    - Respirator articles; breathing “resistance” papers
    - Occupational studies; lab investigations
    - Speech ventilation; coughing and sneezing flow rates
  - Article reviews in-progress

- Data Compilation
  - Initial collection of raw flow rate data from ECBC and UMCP; additional sources TBD
    - Current data formatted for analysis

- Human Use Testing
  - Pilot testing of speech flow rates with respirator initiated late September 2003

Occupational Literature Review

Citation	Test-type	Tasks	Ventilation Rate ($L^{?}$ min^{-1})
Kurumatani *et. al.* (1992)	Worksite	Felling trees	22.3 – 37.8
Wakui *et. al.* (2002)	Worksite	Nursing home care (day & night shifts)	13 (day) 13.8 (night)
Gallagher and Hamrick (1992)	Simulated	Lifting of mine materials	21 – 27
Gunn *et. al.* (2002)	Simulated	a) Walking b) Sweeping c) Window cleaning d) Vacuuming e) Mowing	a) 26.3 ± 5.3 b) 22.5 ± 4.0 c) 25.0 ± 4.5 d) 19.8 ± 3.5 e) 35.0 ± 5.5
Bridger *et. al.* (1997)	Simulated	Shoveling sand	64.1 ± 16.1 63.5 ± 13.6
Hagen *et. al.* (1993)	Worksite	Motor-manual wood cutting	42.5 ± 7.5
Smolander *et. al.* (1995)	Worksite (controlled)	Manual snow clearing	60.5 ± 11.3 65.8 ± 11.3

Occupational Literature Review: Respirator Use

Citation	Test-type	Respirator	Tasks	Ventilation Rate ($L^{?}$ min^{-1})
Sothmann *et. al.* (1992)	Worksite	SCBA	Fire-suppression	57.0 ± 19.3
Lusa *et. al.* (1993)	Simulated	SCBA	Smoke-diving (in heat)	54 ± 10
Louhevaara *et. al.* (1985)	Worksite(s)	a) Half-mask w/dust filters	a) Building demolition	a) 24 – 48
		b) Half/full-masks w/dust & gas filters	b) Foundry work	b) 16 – 33
		c) Air-line (full mask, pressure demand type)	c) Sandblasting	c) 20 – 27.5
		d) Air-line (half-mask, demand type)	d) Metal spraying	d) 17.5
		e) SCBA	e) Smog-diving, repair & rescue	e) 45 – 70

CDC Workplace Safety and Health

NIOSH

Laboratory Testing Review: Applied Resistances

Citation	Test-type	Resistance Condition	Tasks	Ventilation Rate ($L^{?}$ min^{-1})
Jette *et al.* (1990)	Progressive exercise	APR w/different resistances	Treadmill walk to exhaustion	101.8 ± 16.3 to 132.7 ± 23.6
Louhevaara *et. al.* (1985)	Progressive exercise	SCBA	Treadmill walk	19 - 62
Harber *et al.* (1988)	Constant rate exercise	Single-use acid-mist cartridge	Different intensity treadmill walks	11.9 ± 2.6 to 53.2 ± 13.7
Lerman *et al.* (1983)	Constant rate exercise	"Facemask" w/different resistances	Exhaustive run @ 80% of max	87.4 ± 3.5 to 106.0 ± 4.3
Johnson *et al.* (1997)	Constant rate exercise	APR w/different resistances	Exhaustive walk @ 85% of max	49.7 ± 17.6 to 77.65 ± 30.0
Harms *et al.* (2000)	Constant rate exercise	Mesh screens (3 – 7 $cmH_2O/L/s$)	Exhaustive cycling @ 90% of max	164.0 ± 6.5

CDC Workplace Safety and Health

NIOSH

Laboratory Testing Review: Applied Resistances

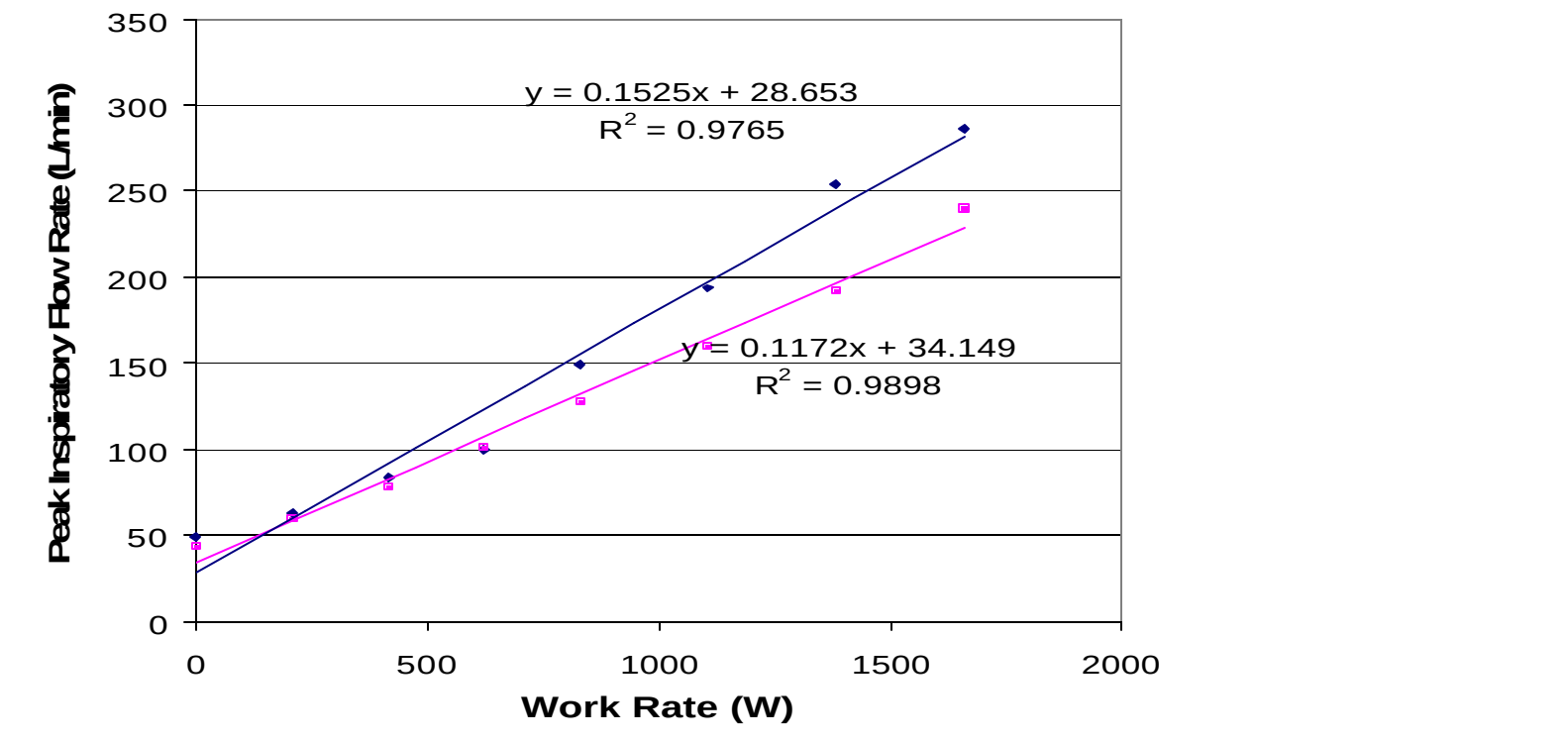
Citation	Test-type	Resistance Condition	Tasks	Ventilation Rate ($L^{?}$ min^{-1})
Jette *et al.* (1990)	Progressive exercise	APR w/different resistances	Treadmill walk to exhaustion	101.8 ± 16.3 to 132.7 ± 23.6
Louhevaara *et. al.* (1985)	Progressive exercise	SCBA	Treadmill walk	19 - 62
Harber *et al.* (1988)	Constant rate exercise	Single-use acid-mist cartridge	Different intensity treadmill walks	11.9 ± 2.6 to 53.2 ± 13.7
Lerman *et al.* (1983)	Constant rate exercise	"Facemask" w/different resistances	Exhaustive run @ 80% of max	87.4 ± 3.5 to 106.0 ± 4.3
Johnson *et al.* (1997)	Constant rate exercise	APR w/different resistances	Exhaustive walk @ 85% of max	49.7 ± 17.6 to 77.65 ± 30.0
Harms *et al.* (2000)	Constant rate exercise	Mesh screens (3 – 7 $cmH_2O/L/s$)	Exhaustive cycling @ 90% of max	164.0 ± 6.5

CDC Workplace Safety and Health

NIOSH

PIFR Literature

- PIFR = Peak Inspiratory Flow Rate
- Limited Database
  - PIFR decreases as resistance increases for both constant-rate exercise and rest



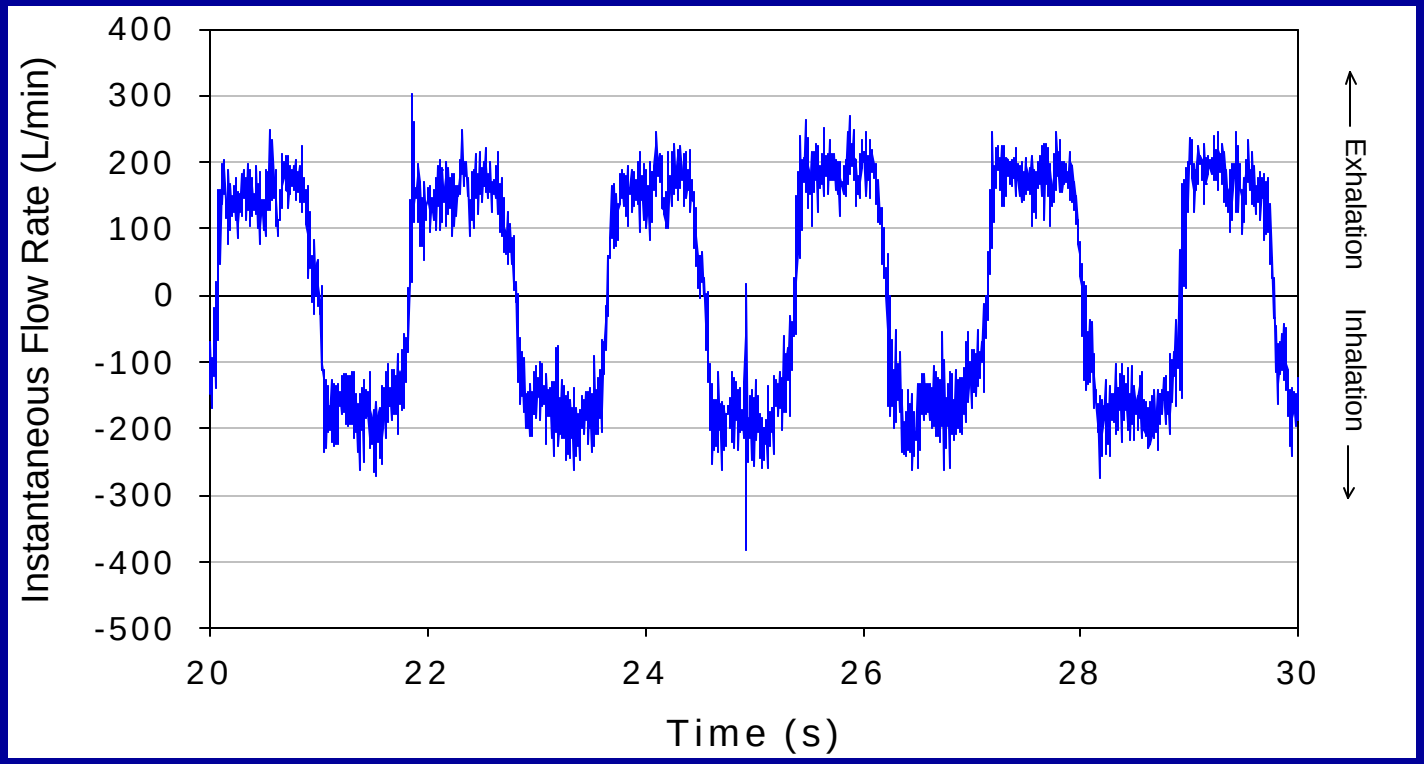
CDC Workplace Safety and Health

NIOSH

Data Compilation

- UMCP data set - Coyne (2001):
- Breath-by-breath values & minute averages at 5 work rates
  - Inspiratory & expiratory time (T_I, T_E)
  - Tidal volume (V_T)
  - Minute ventilation (V_I & V_E)
  - Respiratory rate (f)
  - Mean inspiratory flow rate (V_T / T_I)
  - Duty cycle (T_I /T_{TOT})
  - Peak inspiratory & expiratory flow rate (PIFR, PEFR)
  - PIFR/V_I and PEFR/V_E
- Breathing waveform shapes
- With and without inhalation resistances
- Breath-by-breath variability

Data Compilation



TI (s)	TE (s)	f (1/min)	VT (L)	VI (L/min)	VT/TI (L/s)	TI/TTOT	PIFR (L/min)	PEFR (L/min)	PIFR/VE	PEFR/VE
0.94	0.82	34.01	2.16	73.52	2.30	0.53	271.49	302.67	3.69	4.12
1.00	0.84	32.72	2.35	76.94	2.36	0.54	262.26	243.96	3.41	3.17
0.89	0.82	34.93	2.16	75.45	2.42	0.52	383.51	268.75	5.08	3.56
0.86	0.92	33.79	2.42	81.92	2.82	0.48	263.58	245.27	3.22	2.99
0.89	0.89	33.57	2.43	81.58	2.72	0.50	275.44	245.27	3.38	3.01

Project Milestones

- Complete literature review — Oct 03
- Provide flow rates for NIOSH sponsored high flow filter testing — Nov 03
- Draft report of literature review — Jan 04
- Develop/implement data-gap testing — Jan 04
- Complete compiled data analysis — Mar 04
- Final flow rate recommendations — Aug 04